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APPLICATION FOR PATENT

TITLE: **SYSTEM AND METHOD FOR BEST EFFORT SCHEDULING**

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FIELD OF THE INVENTION

[0001] The present invention relates to access points for wireless devices. In particular, but not by way of limitation, the present invention relates to systems and methods for best effort scheduling of an access point's transmission slots.

BACKGROUND OF THE INVENTION

[0002] The proliferation of portable, wireless devices has created a high demand for systems and methods to provide connectivity to various networks. One protocol that has been developed to provide such connectivity is Bluetooth, which is described in *The Specification of the Bluetooth System*, v1.0 B, December 1, 1999 and is incorporated herein by reference. Bluetooth defines a communication protocol for wireless devices, such as personal digital assistants (PDAs). For example, FIGURE 1 shows one implementation of a Bluetooth system 100 that includes a plurality of access points 115 connected to servers 120 through a network 110. Wireless devices 105 that are near the access points 115 can interact with the servers 120 through one of the access points 115. In some systems, the wireless devices 105 can access other devices such as peripheral devices, private networks, other wireless systems, etc.

[0003] Typically, Bluetooth-enabled access points have limited range and limited connection capacity. Bluetooth, for example, presently limits to seven the number of wireless devices that can actively connect to an access point. Additionally, Bluetooth limits the interaction between an access point and the wireless devices connected to it.

For example, a wireless device can only transmit data to the access point when it is polled by that access point. To prevent blocking, i.e., to prevent one wireless device 105 from using all of the bandwidth, an access point 115 is required to poll each actively connected wireless device every N transmission slots, where N is defined by the clock accuracy of the wireless devices, by default, or by quality of service (QOS) parameters. In a simplified example, if there were five transmission slots per cycle and five wireless devices, then each device would get polled once per cycle.

[0004] This type of round robin scheduling assumes that each wireless device has the same amount of data to upload to the access point and that the upload rate will be constant. Modern communications, however, tend to be bursty rather than constant, and because Bluetooth does not define a method for addressing the bursty flow of data, present systems cause some wireless devices to be idle when they could otherwise be uploading data to the access point. Consider, for instance, the hypothetical case with ten transmission slots per cycle and five wireless devices connected to one of the access points. As before, each wireless device should get polled at least once each cycle. Present access points, for example, would poll the five wireless devices in the first five transmission slots and then poll none of the devices during the next five transmission slots. Table 1 illustrates the transmission slot allocation of such present access points. As is illustrated, no wireless device is capable of uploading data to the access point during transmission slots 6-10.

Transmission Slot	1	2	3	4	5	6	7	8	9	10
Device Being Polled	1	2	3	4	5	EMPTY	EMPTY	EMPTY	EMPTY	EMPTY

TABLE 1: Transmission slot allocation

[0005] By not allocating the empty transmission slots, e.g., slots 6-10, to any wireless device, present access points waste precious bandwidth and slow the exchange of data with wireless devices. Because high bandwidth is one key to commercial success of Bluetooth-based and other wireless devices, a system and method is needed to better utilize transmission slots available to access points.

SUMMARY OF THE INVENTION

[0006] Exemplary embodiments of the present invention that are shown in the drawings are summarized below. These and other embodiments are more fully described in the Detailed Description section. It is to be understood, however, that there is no intention to limit the invention to the forms described in this Summary of the Invention or in the Detailed Description. One skilled in the art can recognize that there are numerous modifications, equivalents and alternative constructions that fall within the spirit and scope of the invention as expressed in the claims.

[0007] The present invention can provide a system and method for increasing bandwidth usage between an access point and a wireless device. One embodiment of the invention can include an access point, a prioritizer, and a priority storage device. Together, these components can increase bandwidth usage between an access point and a wireless device by allocating previously unused transmission slots.

[0008] For example, the access point can establish an initial polling rate with a number of wireless devices and poll each of those devices according to that established rate. For Bluetooth-enabled wireless devices, data can generally only be transferred to the access point after being polled by the access point. Thus, the number of times that the access point polls a wireless device is directly related to the amount of data that the device can upload to the access point. The wireless devices, however, are not required to upload data responsive to being polled and in many cases do not.

[0009] Whether or not a particular device uploads data responsive to being polled, the amount of data--or lack thereof--that a wireless device transfers to the access point can be stored and used to calculate a priority for that device. If, for example, a particular wireless device transferred the maximum allowed amount of data to the access point, it could receive a higher priority than a device that transferred a small amount of data. Some embodiments of the present invention, however, store indicators other than the amount of data. For example, one embodiment involves the wireless device transmitting to the access point a flag that indicates that more data needs to be uploaded.

[0010] The priority assigned to a particular wireless device could be based solely upon the previous cycle's uploading activity, or it could be based upon the uploading activity in a number of previous cycles. For example, a priority can be assigned to a wireless device based upon uploading activity for the wireless device over the prior three cycles. In this type of system when multiple cycles are used to calculate the priority, the priority can be based on a straight average of the uploading activity over the last few cycles or based upon a weighted average of the uploading activity over the last few cycles. Of course, those of skill in the art could calculate the priority factor in a number of ways using any number of polling cycles.

[0011] Using the calculated priorities for the wireless devices actively connected to the access point, one embodiment of the present invention can allocate otherwise unallocated transmission slots to the wireless device(s) with a higher priority. In other words, an access point can poll a wireless device with a high priority during a time slot that previously would have gone unused. Transmission slots that are allocated based upon priority are referred to as priority allocated transmission slots.

[0012] In some embodiments, all unallocated transmission slots are allocated to the single wireless device with the highest priority, and in other embodiments, the unallocated transmission slots are divided among multiple higher priority devices. In either case, however, a wireless device's uploading activity during these priority allocated transmission slots can be recorded and used to modify the priority for that wireless device. For example, if the wireless device receives five priority allocated transmission

slots and only fully uses three of them, that device's priority can be reduced, thereby possibly making the unused transmission slots in the next cycle available to some other wireless device.

[0013] As previously stated, the above-described embodiments and implementations are for illustration purposes only. Numerous other embodiments, implementations, and details of the invention are easily recognized by those of skill in the art from the following descriptions and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Various objects and advantages and a more complete understanding of the present invention are apparent and more readily appreciated by reference to the following Detailed Description and to the appended claims when taken in conjunction with the accompanying Drawings wherein:

FIGURE 1 is a block diagram of an existing network and network access system;

FIGURE 2 is a block diagram of an existing network access system;

FIGURE 3 is a block diagram of one embodiment of a network access system constructed in accordance with the principles of the present invention; and

FIGURE 4 is a flowchart of one method according to the present invention for operating a network access system.

DETAILED DESCRIPTION

[0015] Referring now to the drawings, where like or similar elements are designated with identical reference numerals throughout the several views, and referring in particular to FIGURE 2, it is a block diagram of an existing network access point 115. In this implementation, the access point 115 is hard-wired to a network 110 (shown in Figure 1). In other versions, however, the access point 115 could be connected to the network 110 through a high-speed wireless link or other link (not shown).

[0016] To access the network 110, a wireless device 105 within range of an access point 115 establishes a connection with that access point. Once a connection is established, the wireless device 105 can receive information from and transmit information to the network 110 via the access point 115. In FIGURE 2, wireless devices 105A, 105B, 105C and 105D are actively connected to the network (shown by dashed line) and wireless device 105E is either not connected or in, for example, a Bluetooth-defined PARK mode.

[0017] Referring now to FIGURE 3, it is a block diagram of one embodiment of a network access system 125 constructed in accordance with the principles of the present invention. This embodiment includes an access point 115', a prioritizer 130, and a priority storage module 135. Although these components are shown separately, one skilled in the art can recognize that the components can be combined and housed as a single component.

[0018] As with the access point 115 described with relation to FIGURE 2, wireless device 105 can establish a connection with the access point 115' of FIGURE 3 and thereby access the network 110. In this embodiment, however, the prioritizer 130 and the priority storage module 135 allocate transmission slots that would not have been allocated by the conventional access point 115 of FIGURE 2. The operation of the inventive access point 115' of FIGURE 3 is best illustrated by reference to the flowchart of FIGURE 4 and the accompanying text.

[0019] Referring now to FIGURE 4, the network access system 125 operates by establishing an initial polling rate for the wireless devices 105A-E (step 140). The method of establishing this polling rate is well known in the art and, thus, is not described herein. After the initial polling rate has been established, the access point 115' begins polling each of the actively-connected wireless devices 105A-E (step 145). The prioritizer records, in the priority storage module 135, the amount of data, or some indicator thereof, that each wireless device 105 uploads to the access point 115'. Using that recorded data, the prioritizer 130 calculates a priority (or ranking) for the wireless devices 105 (step 150). Next, the prioritizer 130 allocates unassigned transmission slots to the wireless device 105 with the highest priority and causes the access point 115' to poll the wireless device 105 for each of those transmission slots (step 155). Assuming that the prioritizer 130 determines that wireless device 105A has the highest priority for the next cycle and that wireless devices 105A-E are actively connected to the access point 115, Table 2 represents an exemplary time slot allocation.

Transmission Slot	1	2	3	4	5	6	7	8	9	10
Device Being Polled	105A	105B	105C	105D	105E	105A	105A	105A	105A	105A

TABLE 2: Transmission slot allocation

[0020] The prioritizer 130 can also record the upload activity of a wireless device 105 during the priority allocated transmission slots and change that device's priority accordingly. For example, the prioritizer can record the activity of wireless device 105A over transmission slots 6-10 as shown in Table 2 and adjust the priority of device 105A to reflect its uploading activity during those time periods.

[0021] In certain embodiments, before a wireless device 105 is finished uploading data to the access point 115', the device 105 may include an indicator, e.g., flag, in the uploaded data that indicates that more data is to follow. When the uploaded data includes such an indicator, the prioritizer 130 can change the device's priority accordingly. For example, if wireless device 105A included an indicator in its uploaded data in transmission slot 7 (as shown in Table 3), that device's priority could be lowered and transmission slots 8-10 reallocated to a different wireless device 105 (step 160). Alternatively, the prioritizer 130 could finish the cycle with the priorities as they are and adjust the priorities for the next cycle. In other words, the access point 115' could still poll wireless device 105A during

transmission slots 8-10 despite receiving an end-of-upload indicator. Device 105A's priority, however, could be changed for the next cycle.

Transmission Slot	1	2	3	4	5	6	7	8	9	10
Device Being Polled	105A	105B	105C	105D	105E	105A	105A	105D	105D	105D

TABLE 3: Transmission slot allocation

[0022] In conclusion, the present invention provides, among other things, a system and method for increasing bandwidth usage between an access point and a wireless device. Although embodiments of the present invention are described with relation to Bluetooth and access points, those skilled in the art can readily recognize that numerous variations and substitutions may be made in the invention, its use and its configuration to achieve substantially the same results as achieved by the embodiments described herein.

Accordingly, there is no intention to limit the invention to the disclosed exemplary forms. Many variations, modifications and alternative constructions fall within the scope and spirit of the disclosed invention as expressed in the claims.